Setting the radiometric scale for CERES instruments

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Opening Remarks

- CERES Earth's radiation budget set consists of measurements taken by 5 different instruments and spans 12 years (1998-2009)
- The same radiometric scale to be set at the beginning of a mission in March, 2000 for Terra; and July, 2002 for Aqua
- FM1 is selected to be the climate instrument:
  - Produces the longest, continuous data set
  - Shows the smallest spectral changes for the mission
  - Shows the best the 3-channel consistency
  - Shows the smallest day-night difference
  - Has been used to compare with AQUA since 2002

Test to set FM1 as reference

- Direct compare of FM1 and FM2 based on ES8:
  - Proposed Edition 3 data for March 2000
  - Comparison at the unfiltered radiance level
    - matched geometry of measurements for VZA $< 60°$
    - $|VZA_{FM1} - VZA_{FM2}| < 3°$ & $|RAZ_{FM1} - RAZ_{FM2}| < 3°$
  - 1500 comparison regions for day or night per month
  - Averaging over $1° \times 1°$ grid
  - For all three channels and all scene types

Complementary Tests

- Direct compare of FM1 or FM2 and PFM:
  - The same approach as for Terra using ES8
    - Edition 2, March 2000 PFM data
    - PFM geometry matched by FM1 or FM2 (PAPS mode)
- DCC SW albedo
  - SSFs used to define deep convective clouds
- Direct compare of FM1 and FM2 based on SSFs
  - CLRO and DCC subsets
  - Near nadir measurements
  - Imager information in selecting matched footprints
- Direct compare of Terra footprints at nadir (ES8N)

(FM2 – FM1) results for all-sky LW

$\alpha = 95\%$ or 2δ

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
LWd - Ed3	73.73	0.04	0.05	0.37	1268	0.03
LWn - Ed3	70.24	-0.28	-0.40	0.28	1516	0.02

Edition3:
LW day shows no difference
LW night shows statistically significant difference of
$0.40 \pm 0.02\%$

(FM1 or FM2 – PFM) results for all-sky LW

Unfiltered Radiance	μ FM1	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
LWd - Ed3	85.69	-0.08	-0.10	0.58	152	0.11
LWn - Ed3	80.98	-0.46	-0.56	0.38	152	0.08

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
LWd - Ed3	85.59	-0.04	-0.05	0.52	151	0.10
LWn - Ed3	80.57	-0.78	-0.97	0.38	151	0.08

Daytime LW: (FM2-PFM) – (FM1-PFM) = 0.05 ± 0.10%

Nighttime LW: (FM2-PFM) – (FM1-PFM) = -0.41 ± 0.08%

(FM2 – FM1) nadir-only all-sky LW

Fluxes	Δμ [%]	α-test [%]
LWd – ES8N	0.03	0.08
LWn – ES8N	-0.43	0.07

All three tests for all-sky LW show that:
there is no difference for daytime
there is the same difference for nighttime

(FM2 – FM1) results for CLRO LW

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
LWd - SSF	95.81	-0.15	-0.15	0.36	110	0.31
LWn - SSF	97.82	-0.32	-0.33	0.34	1840	0.02
LWd – ES8	88.29	-0.16	-0.18	0.38	565	0.04
LWn – ES8	91.70	-0.37	-0.40	0.26	451	0.03

Edition3:

LW day shows statistical difference for ES8 of $0.18 \pm 0.04\%$

LW night shows statistically significant difference of 0.33 or $0.40 \pm 0.03\%$

(FM2 – FM1) results for Cloudy LW

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test %
LWd - SSF	34.75	1.09	3.14	0.28	30	0.29
LWn - SSF	34.53	0.01	0.02	0.34	68	0.26
LWd – ES8	59.95	0.28	0.46	0.79	998	0.08
LWn – ES8	57.17	-0.16	-0.29	0.52	1306	0.05

Edition3:
LW day shows statistically significant difference of
-0.46 ± 0.08%
LW night shows statistically significant difference of
0.29 ± 0.05%

(FM2 – FM1) nadir-only LW for CLRO and Overcast

Fluxes CLRO	Δμ [%]	α-test [%]
LWd – ES8N	-0.12	0.06
LWn – ES8N	-0.41	0.06

Fluxes Ovcast	Δμ [%]	α-test [%]
LWd – ES8N	0.34	0.11
LWn – ES8N	-0.45	0.10

For both scene types, the differences are consistent between comparison based on ES8 and ES8N
FM1/2 - PFM results are also qualitatively consistent.

(FM2 – FM1) results for all-sky SW

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
SW - Ed3	72.72	-0.16	-0.22	0.37	699	0.07

Edition3:
SW shows statistically significant difference of
0.22 ± 0.07 %

(FM1 or FM2 – PFM) results for all-sky SW

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
SW - Ed3	70.93	-0.24	-0.34	1.97	41	0.87

Unfiltered Radiance	μ FM1	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
SWd - Ed3	73.63	0.20	0.28	3.45	70	1.12

SW: (FM2-PFM) – (FM1-PFM) = -0.62 ± 1.12%

This is qualitatively consistent with the direct difference

(FM2 – FM1) nadir-only all-sky SW

Fluxes	Δμ [%]	α-test [%]
SW – ES8N	-0.26	0.21

All three tests for all-sky SW show that:
Qualitatively FM1 > FM2
Quantitative result can only be based on the direct comparison

(FM2 – FM1) results for CLRO SW

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
SW - SSF	20.35	0.05	0.17	0.76	110	0.46
SW – ES8	27.15	0.24	0.88	0.93	413	0.34
SW – ES8N			-0.21			0.19

(FM2 – FM1) results for Cloudy SW

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
SW - SSF	347.78	-0.42	-0.13	0.76	140	0.27
SW – ES8	105.81	-0.46	-0.44	1.93	705	0.14
SW – ES8N			-0.36			0.36

Edition3:
SW shows statistically significant difference of
0.44 ± 0.14%

DCC albedo results

CERES ES8	Number of footprints	albedo	α-test	WN	α-test
FM1	448	0.705	0.006	0.863	0.009
FM2	544	0.700	0.006	0.852	0.008

CERES SSF	Number of footprints	albedo	α-test
FM1	145	0.721	0.002
FM2	140	0.720	0.001

FM1 albedo is about 0.5% higher than FM2,
but α-test shows no statistical difference

(FM2 – FM1) results for all-sky WN

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test %
LWd - Ed3	5.14	-0.02	-0.47	0.02	699	0.03
LWn - Ed3	4.81	-0.02	-0.45	0.03	1516	0.03

WN day and WN night show statistically significant difference of 0.47 & 0.45 ± 0.03 %

(FM1 or FM2 – PFM) results for all-sky WN

Unfiltered Radiance	μ FM1	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
WWd - Ed3	6.91	-0.03	-0.37	0.09	70	0.29
WWn - Ed3	6.24	-0.01	-0.17	0.05	152	0.13

Unfiltered Radiance	μ FM2	Δμ	Δμ [%]	σΔ	N smpls	α-test [%]
LWd - Ed3	6.88	-0.06	-0.84	0.06	41	0.25
LWn - Ed3	6.21	-0.03	-0.53	0.05	151	0.13

Daytime WN: (FM2-PFM) – (FM1-PFM) = -0.47 ± 0.29%

Nighttime WN: (FM2-PFM) – (FM1-PFM) = -0.36 ± 0.13%

Required shifts at the BOM

- Direct compare and other tests show satisfactory consistency, and statistically significant differences (@ 2 sigma level) in all 3 channels:
- For the TOT channels
  - FM2 should be raised by 0.40 ± 0.03%
- For the SW channels
  - FM2 should be raised by 0.22 ± 0.07%
- For the WN channels:
  - FM2 should be raised by 0.45 ± 0.03%

Programmable Azimuth Plane Scan (PAPS)

- Objectives of special observations using PAPS:
  - ✓ Earth targets
  - ✓ Matching viewing geometry of other instruments
  - ✓ Sampling within required scan plane orientation

PAPS mode was used in March of 2000 to match viewing geometries of PFM and FM1/FM2

FM1 in PAPS to match PFM

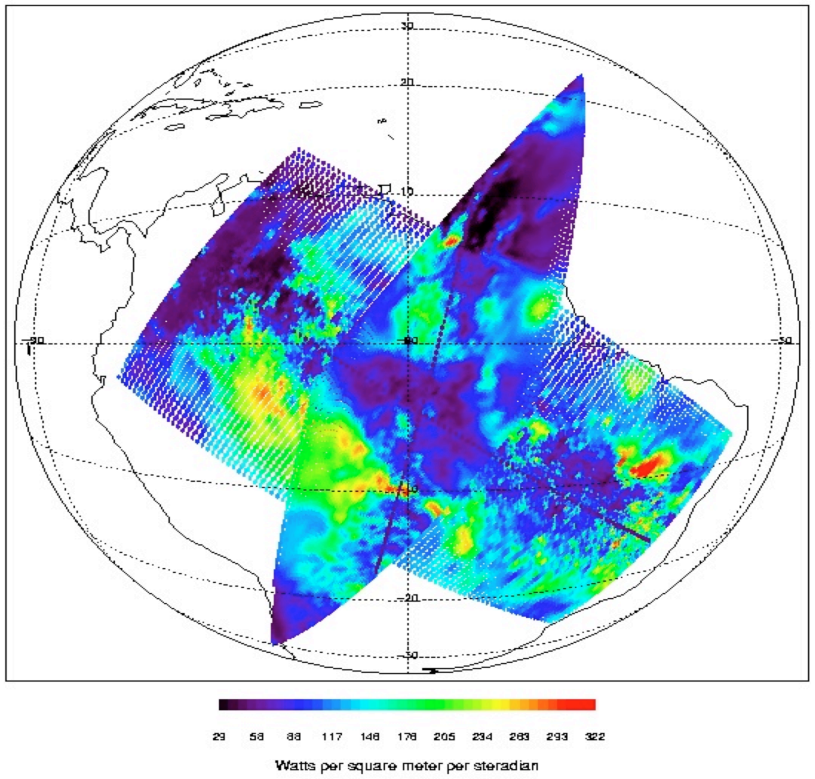


Figure 6. PFM and FM1 scanning patterns during an orbital crossing; their relative azimuth angles coincide.

Matching criteria:

VZA < 10°
RAZ < 20°
ΔT < 15 min
on 1° × 1° gridbox

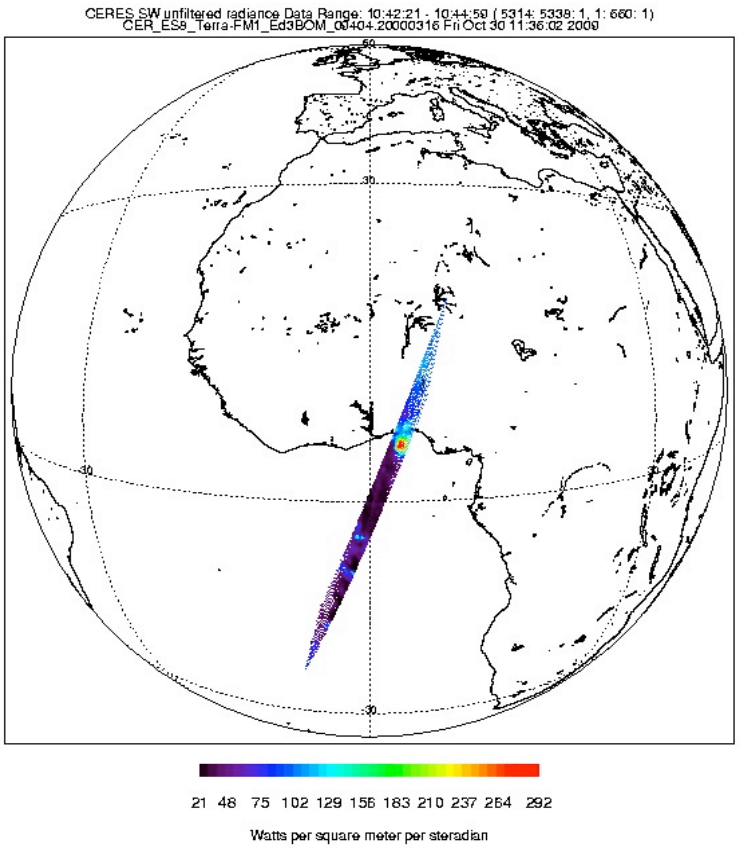
Averaging:

75% of gridbox area has to be covered
OrbX > 4 gridboxes
OrbX is statistically independent average

PAPS schedule in March 2000

Campaign	Duration	Orbits	Amount of data
PFM/FM1	03/04-31	85	450 min
PFM/FM2	03/03-30	49	250 min
No PAPS	03/1-2 &13-15	0	0 min

A region for direct compare



March 16
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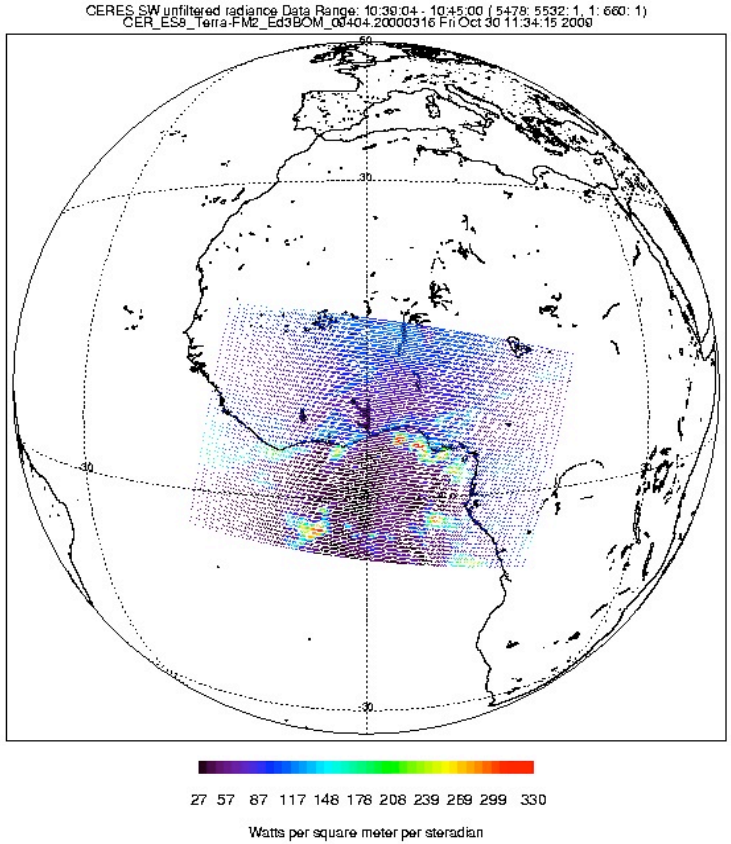
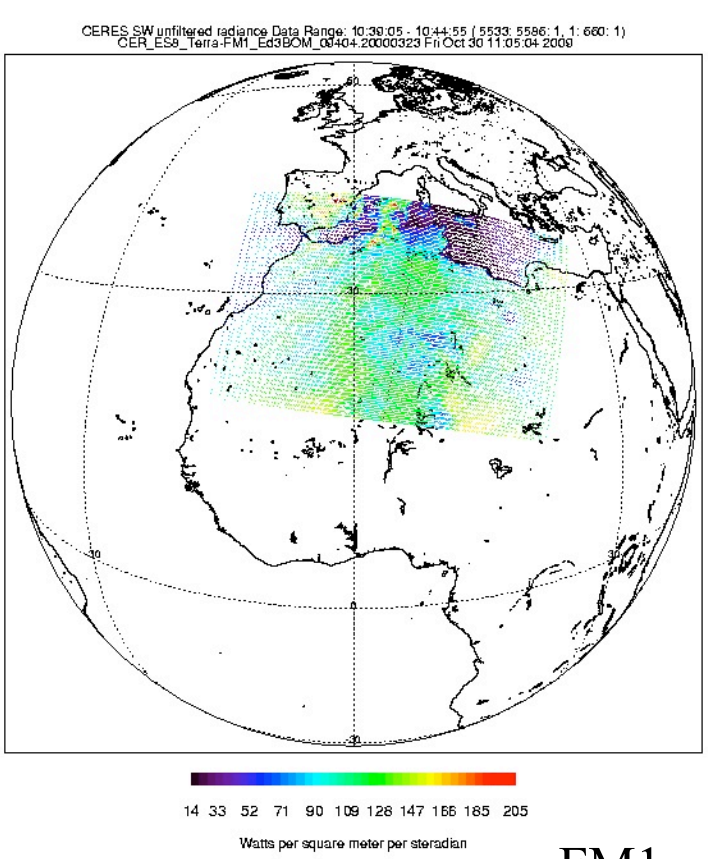


FM1

FM2

A region for direct compare



FM1

March 23
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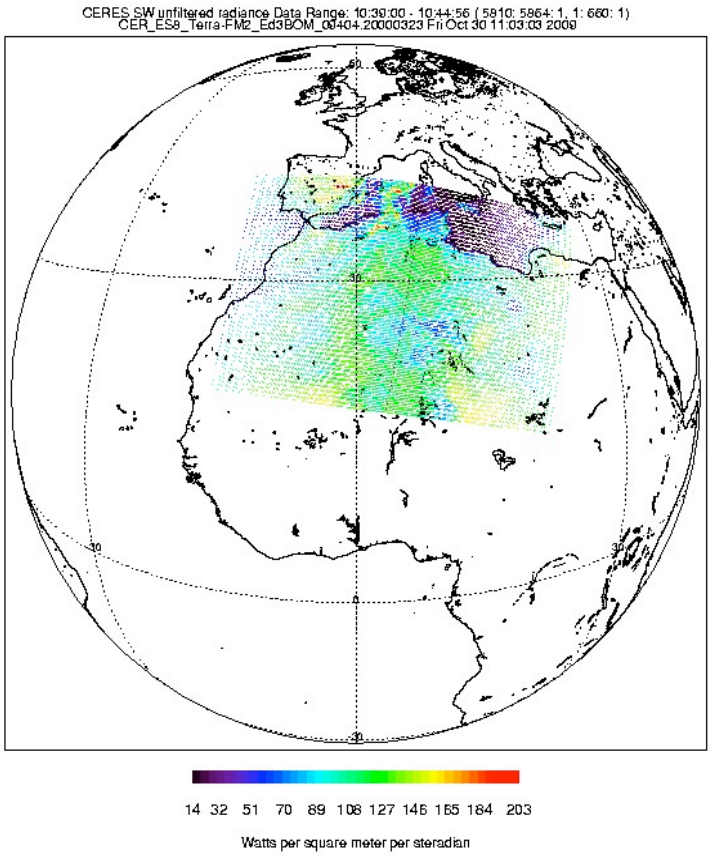

FM2